PROJECT K-7-33
FINAL REPORT FOR COSOMOS 2229
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INTRODUCTION

The following tasks were proposed for the Cosmos project during 1993:

1) Recordings of all preflight candidates during performance of a foot pedal motor control task while in the space capsule mock-up.
2) Recordings of all preflight candidates during locomotion and postural tasks.
3) Recordings of 24-hour spontaneous cage activity in the two flight monkeys before and after flight and of at least three control (non-flight) monkeys after the flight has been completed.
4) Recordings of the foot pedal and motor control tasks during flight and postflight as scheduled.
5) Recordings of the vertical drop test pre, during and postflight for the two flight and three control monkeys.
6) Recordings of locomotion and posture tests of the two flight monkeys postflight.
7) Recordings of locomotion and postural tests of at least three control (non-flight) monkeys during the postflight period.
8) Recalibrate buckles of the two flight and of at least three control monkeys postflight.
9) Analysis of the 24 hour EMG recordings of all monkeys.
10) Analysis of the foot pedal, locomotor and postural motor control tasks for the two flight and three control monkeys.

It was proposed that efforts in the first postflight year be concentrated on the two flight animals and three postflight animals.

RESULTS

Table 1 summarizes the results of preflight recording from the flight pool and indicates ranking determined for this experiment.

Animals 906 and 151 were flown. No preflight 24 hr cage activity or chair trial data was available from 151 following reimplantation of the defective soleus electrode. The first postflight data available for monkey 906 was 25 days after recovery.

24-hour cage activity

Figure 1 shows 24 successive histograms for (a) soleus and (b) medial gastrocnemius throughout a 24 hour period beginning at 12 noon. The first (leftmost) bin, containing the counts of baseline activity has been removed from each histogram. Circadian changes in activity are very clear, with some hours, particularly during the night showing no EMG activity. Activities in other animals showed similar changes throughout the day but with very different absolute values and different relationships between soleus and medial gastrocnemius amplitudes.

Table 2 illustrates this for three juvenile animals from the Cosmos flight pool and compares them with three adult animals recorded at the NASA Ames research facility. Figure 2 summarizes these findings. Though no significant differences were observed due to the large differences in EMG amplitudes recorded among the individual monkeys. The juvenile animals appeared to show lower levels of overall EMG activity than the adults.

Force recordings

During the preflight chair trials, all but two of the implanted force transducers were functional. The two defective transducers had a circuit to ground, indicating a breakdown of electrical insulation. One problem which became apparent during the tests on the remaining transducers was drift to such a degree that compensation modules had to be switched in order to bring the transducer output into a measurable range.

Table 3 summarizes the drift of transducers during our recordings and indicates the compensation modules found to bring the traducers within a usable range.

Figure 3 shows data from one preflight chair trial. The four implanted muscles show normal patterns of EMG activity with force in the medial gastrocnemius muscle following a similar pattern to the EMG activity. Forces during this trial were in the range of 0-1kg, significantly lower than the estimated force output of a monkey medial gastrocnemius muscle (>15kg). At these force levels, the lever excursion was maximal, indicating that the monkey was exerting force against the lever stop. The first second of the trace indicates a sequence where the lever was moved through most of its range and then allowed to return to its original position. There was very little force developed in the medial gastrocnemius muscle during this period and this corresponds to a period of barely detectable EMG in the muscle. There are, however corresponding bursts of activity in the soleus and vastus lateralis muscles. It is highly probable that the soleus muscle developed sufficient force alone to overcome the forces in the lever with vastus lateralis providing extensor torques at the knee. The inset on the right hand side of figure 3 shows the first second of activity displayed at a higher gain. The higher peak in the middle of the force record corresponds to the lever press and indicated that medial gastrocnemius developed less than 50g of force.

Animal 151 had a defective force transducer which was not connected during flight. At the time of launch the transducer on animal 906 had drifted to such a degree that it was outside of the measurable range for the duration of the flight.

Postflight chair trials and calibrations indicated that all the transducers tested were still functional.

The trial on 906 indicated that the transducer was in good condition following the flight. The low levels of force recorded by the transducer during these trials may, as in the preflight trials, indicate that the soleus muscle was generating most of the torque around the ankle.

These findings demonstrate that transducer life is sufficient to provide data for preflight, flight and postflight recordings.

Chair trial EMG activity

Successful chair trial recordings were made on animal 906 preflight, on both animals during flight and postflight. Flight data presented two significant problems. The monkeys performed the motor tasks very poorly during flight, providing very little data to analyze and the EMG amplifiers were set at high gains resulting in clipped signals (figure 4). Analysis of the EMG data was conducted despite the clipped signals and this should be borne in mind when interpreting the data.

Figure 5 tracks amplitudes of soleus and medial gastrocnemius EMG activity in the two flight animals. Animal 906 shows a significant drop in EMG activity in both muscles on the second day in space relative to preflight conditions. Soleus activity appeared to recover only slightly on days 4 and 6 whereas medial gastrocnemius appeared to return to preflight levels. Postflight activity more than 3 weeks after recovery indicates an incomplete recovery of soleus activity and a postflight depression of medial gastrocnemius activity. Preflight activity levels for animal 151 were not available but show a reverse of the trends seen in animal 906. Soleus activity remained at high levels during the flight, even increasing on days 4 and 6 and fell after the return to earth. In contrast, medial gastrocnemius activity was low during the flight and immediately postflight and recovered slightly after 3 weeks.

The previous Bion flight (Cosmos 2044) had indicated a significant change in the relationship between soleus and gastrocnemius activity following spaceflight. We compared this relationship in the current flight by calculating a ratio of mean medial gastrocnemius amplitude to mean soleus amplitude. The findings are illustrated in figure 6. In monkey 151 the ratio of medial gastrocnemius to soleus was low during flight and immediately postflight. This indicated low levels of medial gastrocnemius activity relative to soleus. Three weeks after recovery the ratio has increased substantially, indicating that medial gastrocnemius activity rose relative to soleus. In animal 151 preflight levels and those 3 weeks after recovery had similar, relatively low values. During flight the ratio increased substantially, suggesting that soleus activity decreased relative to medial gastrocnemius activity.

DISCUSSION

The following list summarizes the tasks completed during 6 week preflight recording visit to IMBP in Moscow.

- Modification of EMG connector to improve the reliability of EMG recording.
- 24 hour cage activity recording from all flight candidate animals with the exception of 151 and 1417. Recordings from 151 indicated that the soleus EMG implant had shifted and was no longer recording activity from the soleus muscle. The electrode was reimplanted but no further 24 hour recordings were made.
- Attempts were made to record from flight candidates during the foot lever task. There were intermittent problems with the space capsule mock-up which prevented recordings from some monkeys. Other animals did not perform the foot lever task during recording.
- Force transducer calibrations on all flight candidate animals.
- Time constraints during this visit did not permit the posture, locomotion and drop tests to be conducted during this visit.

The animals chosen for flight were #151 and #906. Neither animal was high on our priority list (see table 1). Nevertheless, both animals provided valuable information.

The following list summarizes the tasks completed during 4 week postflight recording visit to IMBP in Moscow.

- Postflight recordings from flight animals.
- Postflight recordings on 3 control (non-flight) animals.
- Postflight recalibration of force transducers on 1 flight and 4 control (non-flight) animals.
- Attempts were made to record EMG and video data from the flight animals during postflight locomotion and postural activity. EMG data were unusable due to poor reception of the telemetered EMG signal.
- Time constraints during this visit did not permit the 24-hour cage activity and drop tests to be conducted during this visit.

Normal cage EMG activity.

Normal cage activity recorded in the juvenile monkeys at IMBP in Moscow show large differences in the levels of EMG activity recorded from different individuals and different relationships between soleus and medial gastrocnemius muscles in those individuals. These finding parallel those made at NASA Ames on adult animals indicating that, for EMG studies, each animal must be used as its own control.

Force transducer performance

Eight of 10 force transducers were operational before flight and of the 5 transducers tested postflight, all were operational, indicating a potential high probability of success with these transducers in the future.

The low levels of force recorded from the medial gastrocnemius muscle during chair trial activities suggests that a majority of the torque around the ankle may have been generated by the soleus or other combinations of muscles during these trials. The drop in soleus EMG activity in animal 906 flight suggests that this situation may change during flight so that more of the torque may be generated by medial gastrocnemius.

Flight EMG recordings

The flight EMG recordings suggest that significant changes in muscle control may occur in spaceflight. However, the very different observations made in the two animals are somewhat puzzling. The lack of preflight data for animal 151 and of postflight data close to recovery for animal 906 makes comparison with our previous flight (Cosmos 2044) difficult. Animal 151 shows a drop in soleus amplitude from the post recovery recording to the 25-day post recovery recording, in contrast to our observations on flight 2044 where soleus amplitude increased for several days after recovery. A tempting suggestion would be that the soleus and gastrocnemius channels on animal 151 were reversed at some stage of the experimental procedure. This would bring observations on animal 151 more into line with the observations made on animal 906 and

with the animal recorded in our previous flight. At the present time we have no verification of such a switch.

It is also clear from our recordings that levels of EMG recorded during spaceflight can attain values similar to those measured on earth. Amplifier gain settings should therefore probably not be changed for spaceflight.

EDGERTON - MONKEY RANKINGS AS OF 11/1/92

Rank	Animal Number	Comments
1-5	1401, 27892, 25775, 27856, 27803	At this time, these animals are of equal ranking. All flight recorded leg EMGs and the TFT appear to be intact. Performance on the motor task and implant viability should be considered at the time of the final selection.
6	25476 "Houdini"	Currently all leg EMG electrodes and the TFT are working in this animal. However the TFT has been repaired and the durability of the repair is questionable. Also, it is likely that he will get to and damage his implants again.
7	27906	Soleus EMG exhibits an intermittent dropout.
8	26151	Force buckle has leakage to ground. **Do not ground animal if connected to force transducer amplifier, unless you receive prior approval from John Hines.**
9	27907	Force buckle has high noise level. Recordings are useless.
10	27838	Animal does not perform foot lever task

Total Daily Muscle Activity

Monkey Number	Medial Gastrocnemius (mVs)	Soleus (mVs)
I738 (adult)	914	1166
M009 (adult)	935	1970
411 (adult)	1355	1462
M27803 (juv.)	1671	1671
M27892 (juv.)	358	262
M27906 (juv.)	54	499

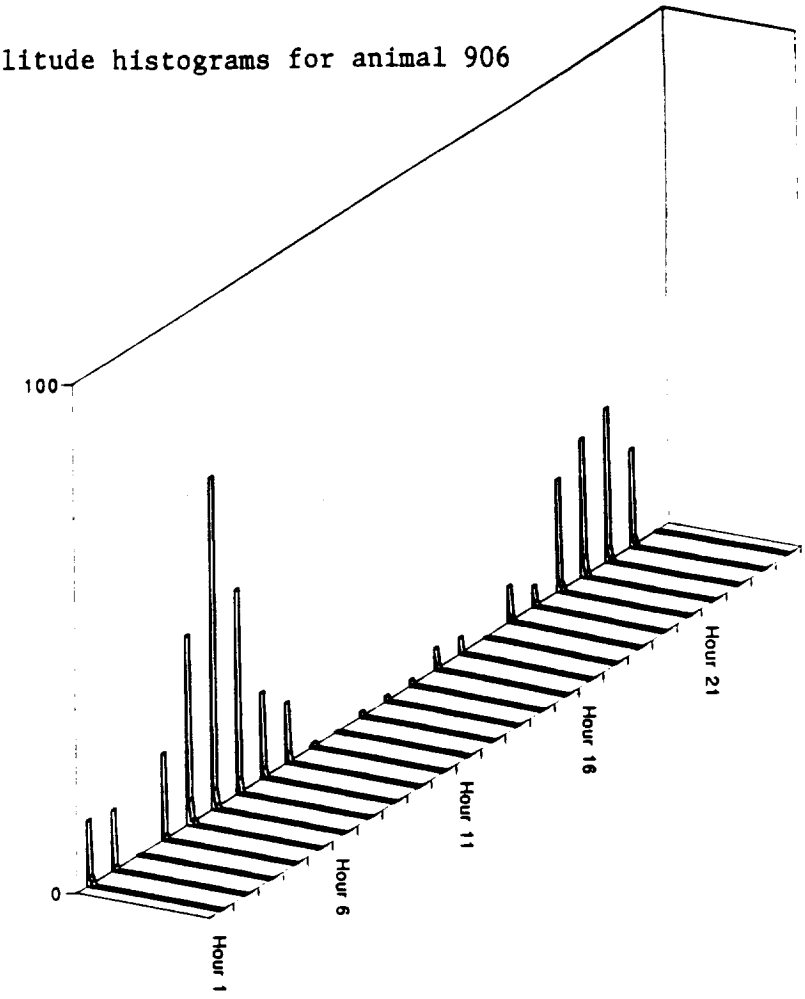
Table 2

ANIMAL #	FORCE TRANSDUCER OFFSET DATE	OFFSET(V)	COMP.MOD
27803	10/8/92	0	17
	10/15/92	-.7	
	10/21/92	-.55	
	10/26/92	-1.2	
27907	10/7/92	10	19
	10/21/92	10	19
	10/30/92	10	19
		3.5	11
1401	10/7/92	0	24
	10/20/92	-2.5	
	10/26/92	-2.8	
	10/30/92	-1.9	
25588	10/21/92	.8	23
26151	10/21/92	1.8	16
	10/27/92	1.2	
	10/29/92	3.6	
27856	10/6/92	Dropout	22
	10/22/92	10	22
	10/26/92	-0.5	19

ANIMAL #	FORCE TRANSDUCER OFFSET DATE	OFFSET(V)	COMP.MOD
27906	10/9/92	0	11
	10/20/92	1.3	
	10/27/92	0.2	
27838	10/12/92	0.5	15
	10/20/92	-0.5	
	10/30/92	1	
25476	10/14/92	1	25
	10/21/92	-1.4	
	10/27/92	-1.4	
	10/28/92	-1.7	
25775	10/8/92	-5	20
	10/20/92	-5	
	10/27/92	-5	
	10/30/92	-5	
1417			Not tested.
27892	10/13/92	-2	18
		0	19
	10/20/92	-3.7	18
		-1.5	19
	10/29/92	-2.8	19

24 hour cage activity amplitude histograms for animal 906

Soleus



Medial
Gastrocnemius

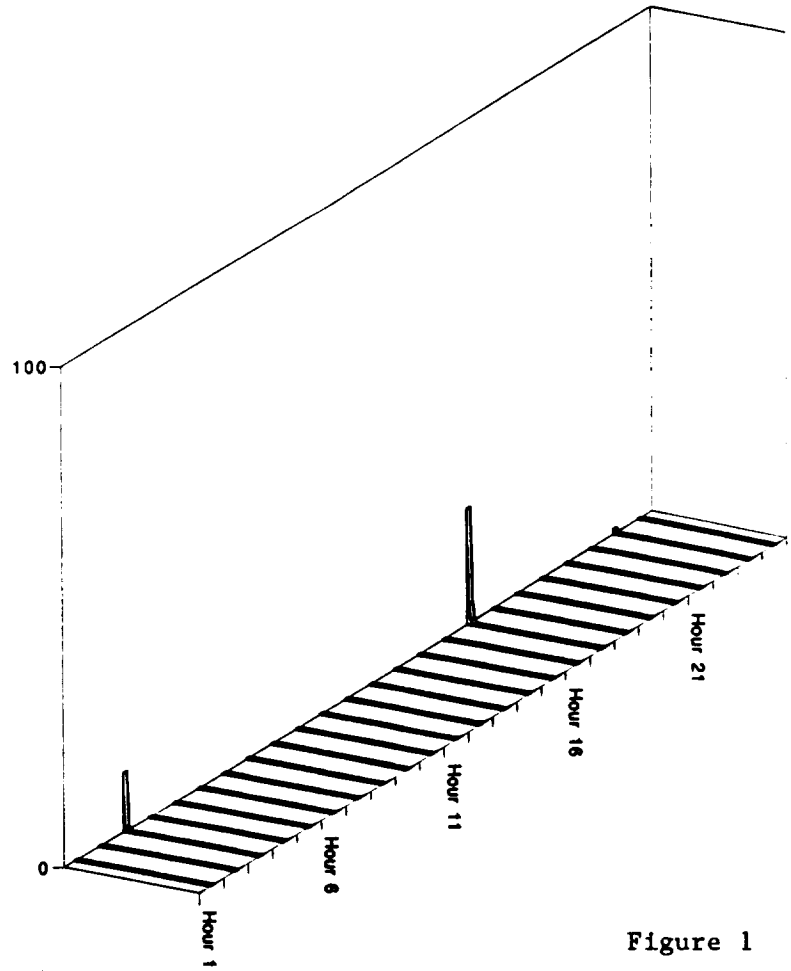


Figure 1

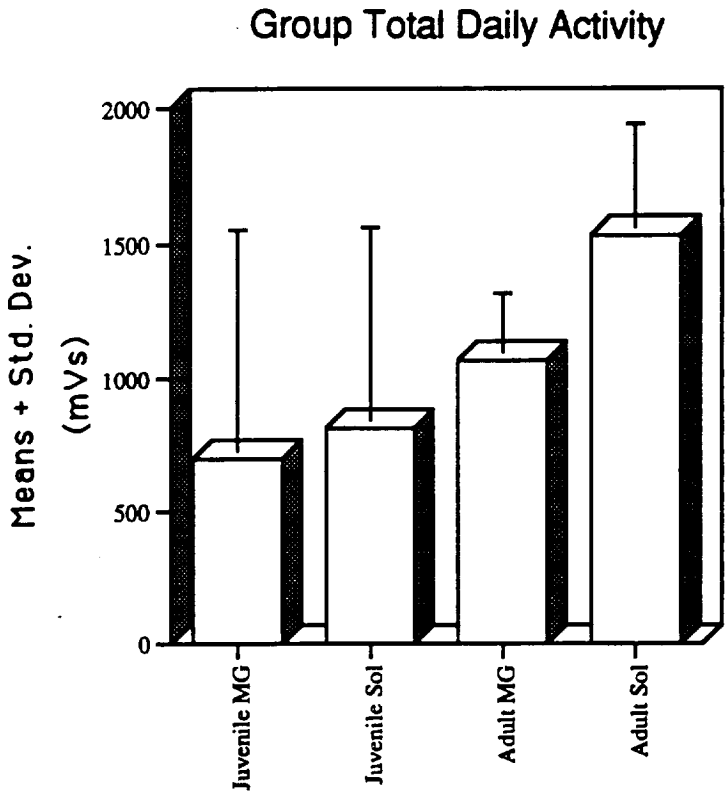

Group Total Daily Activity
Means + Std. Dev.
(mVs)
2000
1500
1000
500
0
Juvenile MG
Juvenile Sol
Adult MG
Adult Sol

Figure 2

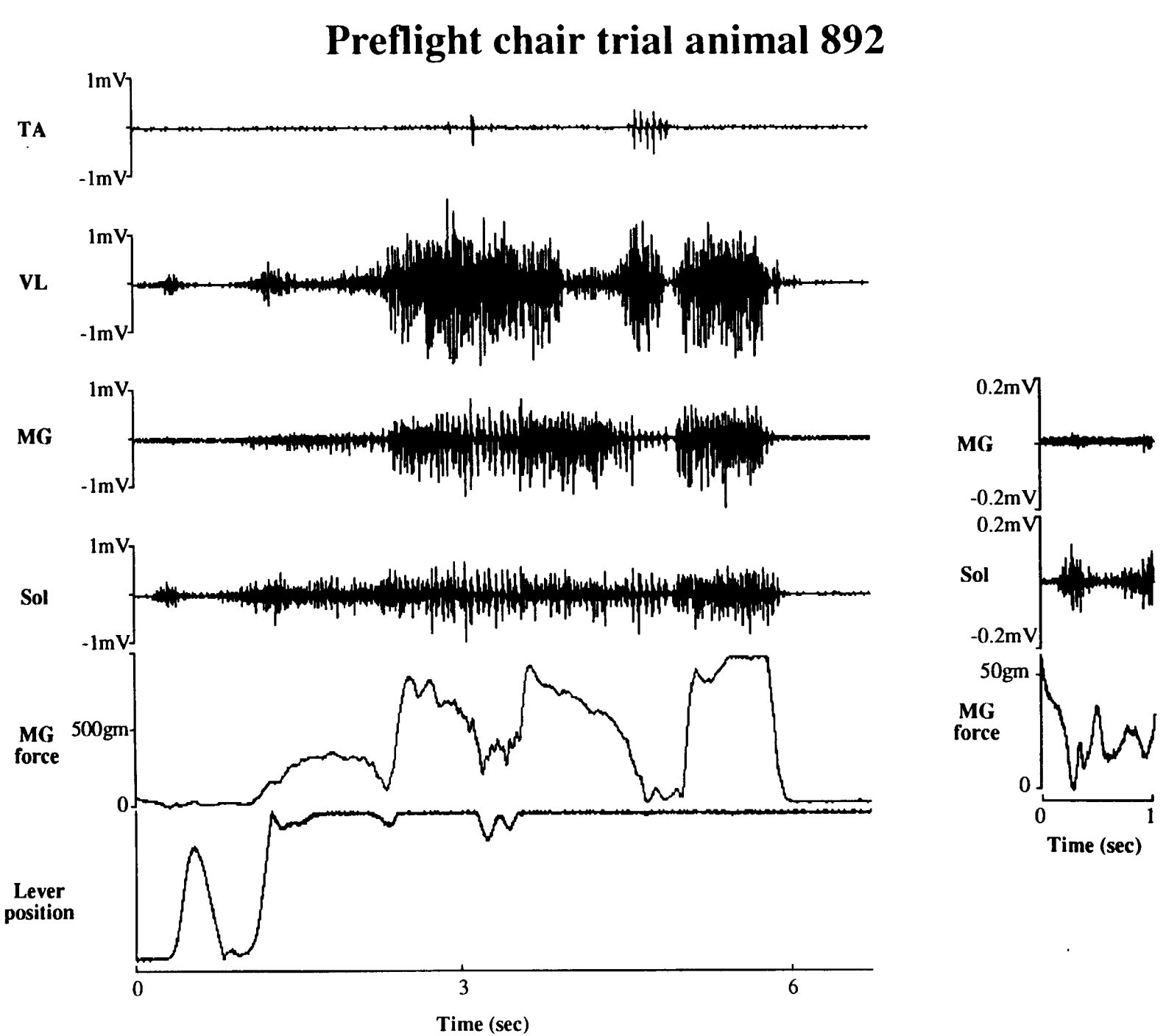

Preflight chair trial animal 892
1mV
TA
-1mV
1mV
VL
-1mV
1mV
MG
-1mV
1mV
Sol
-1mV
MG force
500gm
0
Lever position
0
3
6
Time (sec)
0.2mV
MG
-0.2mV
0.2mV
Sol
-0.2mV
50gm
MG force
0
0
1
Time (sec)

Figure 3

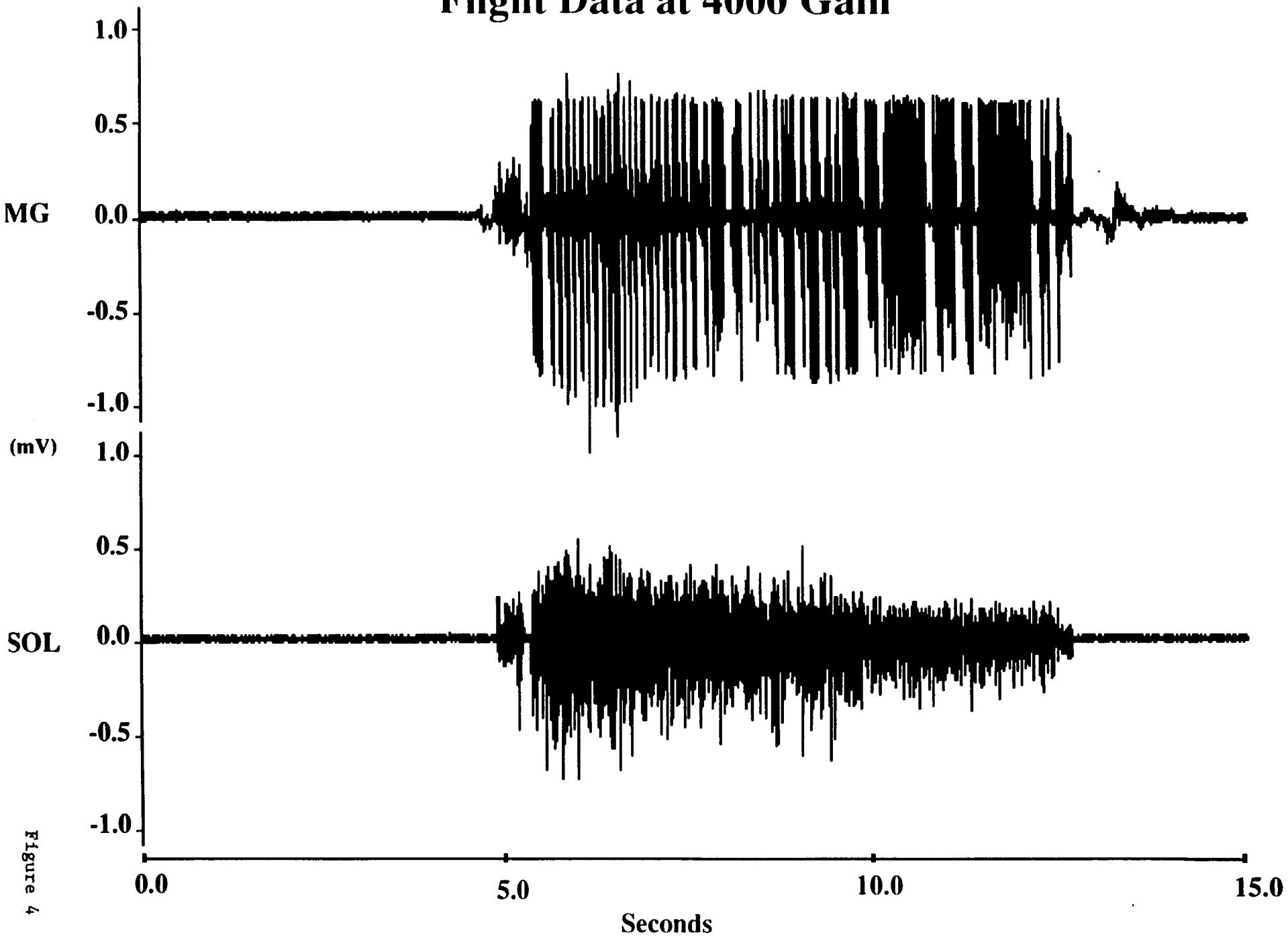

Flight Data at 4000 Gain
MG
SOL
(mV)
1.0
0.5
0.0
-0.5
-1.0
0.0
5.0
10.0
15.0
Seconds

Figure 4

EMG amplitude changes in flight monkeys

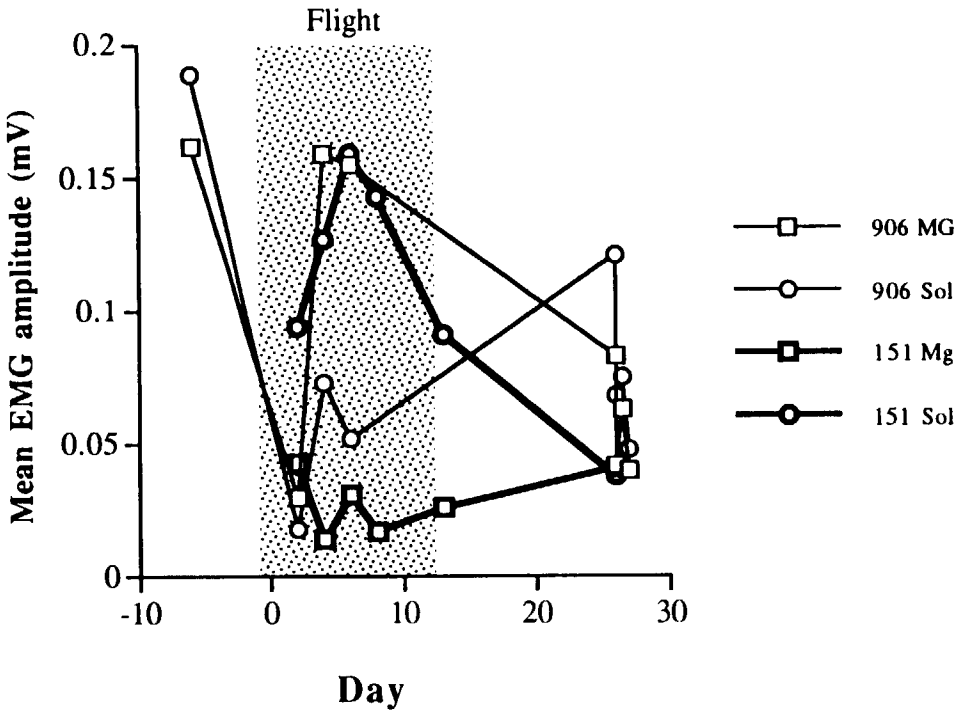


Figure 5

Ratio of Soleus and MG mean amplitudes

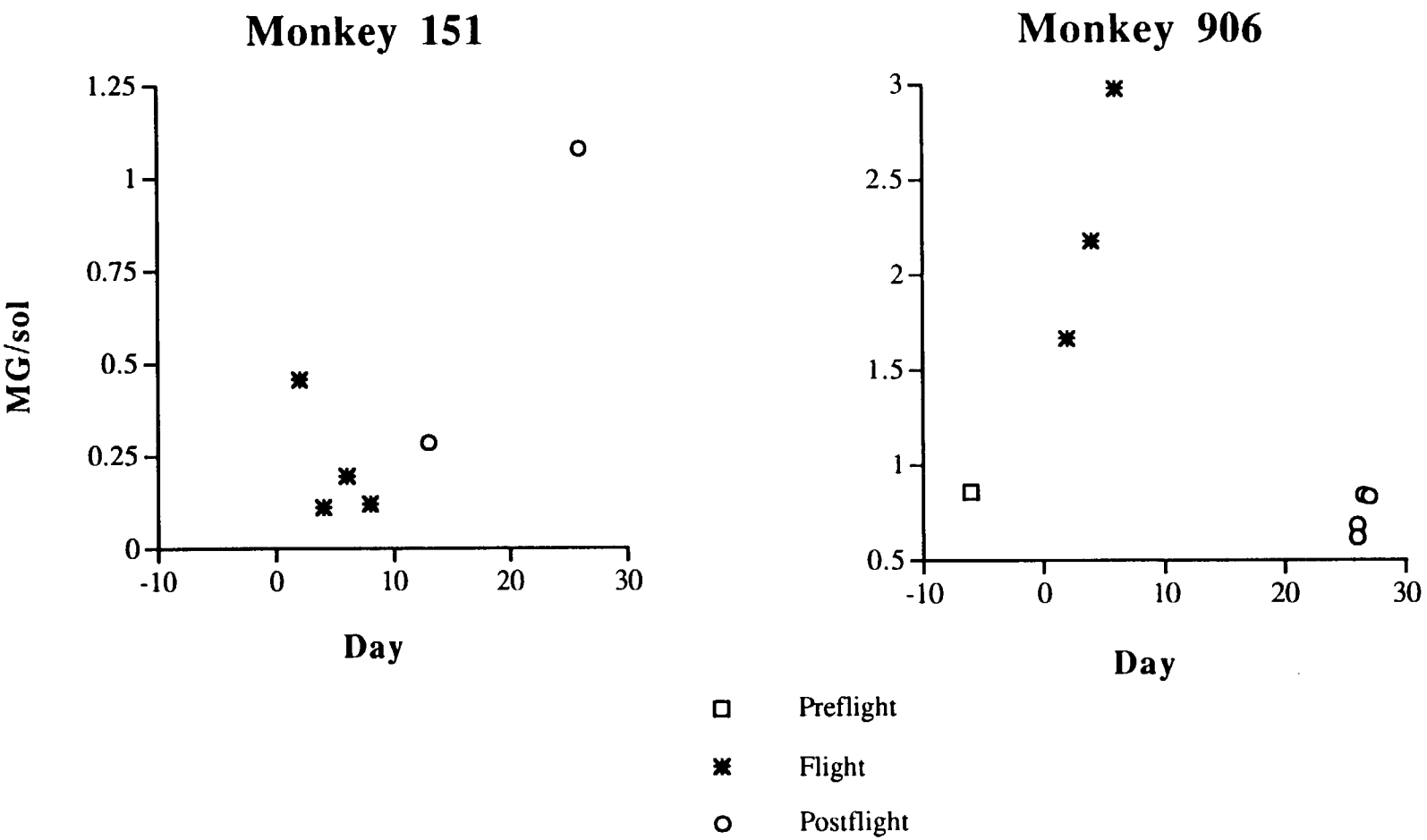


Figure 6